Effects of Alternating Pressure Patterns on Sacral Skin Blood Flow Responses in People with Spinal Cord Injury

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ABSTRACT

This study examined sacral skin blood flow in 10 individuals with spinal cord injury using alternating pressure support surfaces (APSS). Higher blood flow was observed with a 75/5 mmHg pressure amplitude versus 65/15 mmHg, while cycle time had no effect. Findings suggest pressure amplitude plays a key role in promoting tissue viability.

INTRODUCTION

- Individuals with spinal cord injury (SCI) are highly susceptible to pressure injuries due to impaired sensation, reduced mobility, and altered vasomotor control (Mervis & Phillips, 2019; Jan & Brienza, 2006).
- Alternating pressure support surfaces (APSS) aim to prevent pressure injuries by periodically redistributing pressure and reducing ischemic tissue damage (Wu et al., 2020; Jan & Brienza, 2011).
- However, inconsistent outcomes on the effectiveness of APSS have been reported, possibly due to variations in pressure amplitude, frequency, and cycle settings (Shi et al., 2021; Bader, 1990).
- Optimizing APSS settings—particularly pressure amplitude and cycle time, could enhance sacral skin blood flow, thus improving tissue viability and minimizing risk of pressure injury among individuals with SCI.

OBJECTIVE

To examine the effects of different alternating pressure amplitudes (75/5 mmHg vs. 65/15 mmHg) and cycle-time periods (5 min. vs. 2.5 min.) on sacral skin blood flow responses in individuals with spinal cord injury (SCI).

METHODS

Participants:

10 individuals with spinal cord injury (SCI)

- ***Inclusion:*** Injury between C4-T12, aged 18–50 years, manual or powered wheelchair users.
- ***Exclusion:*** Active pressure ulcers, open wounds or recent surgery of less than 3months, diabetes, vascular diseases.

Protocol Development:

- ***Protocol Flow for Each Session:*** 10-min. baseline → 20-min. AP loading → 10-min. recovery

- ***Four Alternating Pressure (AP) protocols tested:***

Differential Pressure Amplitudes	*Differential Cycle-time Periods*
1. 75/5 mmHg, 5-min. AP *(4 cycles: 2.5-min 75 mmHg & 2.5-min 5 mmHg)*	**3. 5-min. AP, 75/5 mmHg** *(4 cycles: 2.5-min 75 mmHg & 2.5-min 5 mmHg)*
2. 65/15 mmHg, 5-min. AP *(4 cycles: 2.5-min 65 mmHg & 2.5-min 15 mmHg)*	**4. 2.5-min. AP, 75/5 mmHg** *(8 cycles: 1.25-min 75 mmHg & 1.25-min 5 mmHg)*

Experimental Procedures:

- ***Measures:***
  - Each participant undergoes two testing sessions separated by 1 week.
  - Skin blood flow at the sacrum measured using laser Doppler flowmetry (LDF).
  - Blood flow is normalized to 10-min. baseline readings; data is recorded continuously.

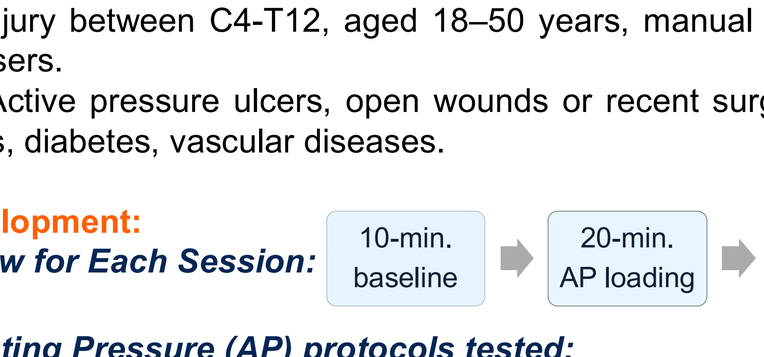


Figure 1: (A) The setting of the indenter and a research participant
(B) The indenter and the load cell used to monitor the applied force/pressure.

Data Analysis:

- Wilcoxon signed-rank tests used to compared skin blood flow responses between protocols during high-pressure and low-pressure phases.
- SPSS (Version 26, Chicago, IL) and MatLab (R2019b, Natick, MA) used for analyses.
- Significance threshold is set at $p < 0.05$.

RESULTS

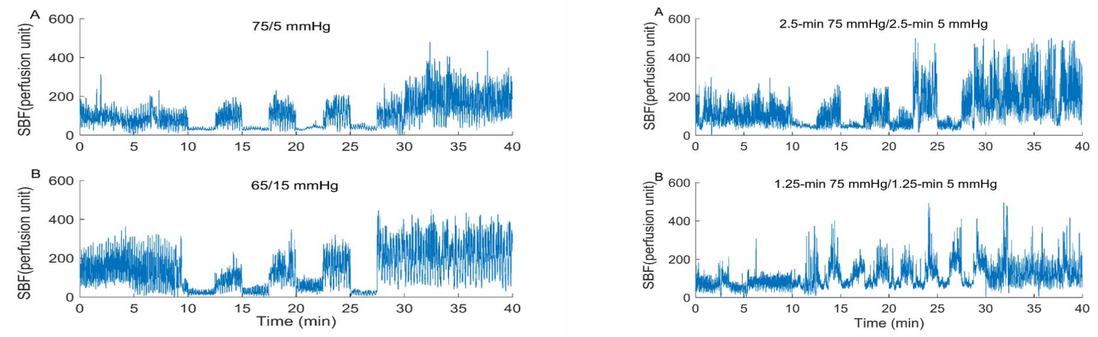


Figure 2: Examples of skin blood flow (SBF) during two AP protocols of different pressure amplitudes and cycle-time periods.

Pressure Amplitude Effects:

- ***High-pressure phase:***

75/5 mmHg (0.3658 ± 0.0688) shows higher normalized skin blood flow than 65/15 mmHg (0.1702 ± 0.0389), $p = 0.0469$

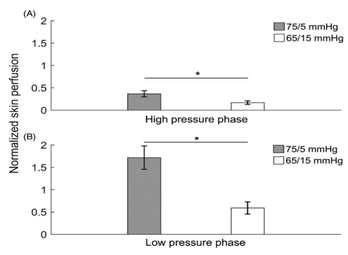


Figure 3: Comparisons of mean normalized skin perfusion (normalized to the baseline) during the high-pressure phase (A) and the low-pressure phase (B) between the 75/5 mmHg protocol and 65/15 mmHg protocol.

The results are represented as mean ± standard error;
* indicates $p < 0.05$.

- ***Low-pressure phase:***

75/5 mmHg (1.7184 ± 0.262) also superior to 65/15 mmHg (0.5916 ± 0.1378), $p = 0.0156$

Cycle-Time Period Effects:

- No significant differences in skin blood flow between 5-min. and 2.5-min. cycles for high- or low-pressure phases ($p = 0.08$).

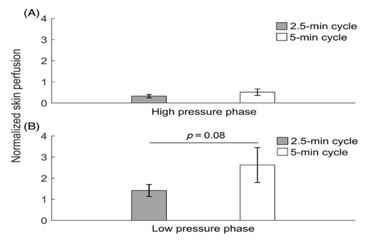


Figure 4: Comparisons of mean normalized skin perfusion (normalized to the baseline) during the high-pressure phase (A) and the low-pressure phase (B) between the protocol of 2.5-min cycle-time period (8 cycles) and that of 5-min cycle-time period (4 cycles).

The results are represented as mean ± standard error.

Recovery Phase:

- No significant differences in skin blood flow observed during recovery periods across all protocols.

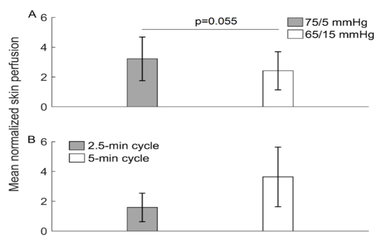


Figure 5: Comparisons of normalized skin perfusion (normalized to the baseline) during the recovery period:
(A) between the protocol of 75/5 mmHg AP and that of 65/15 mmHg AP and
(B) between the protocol of 2.5-min cycle-time period (8 cycles) and that of 5-min cycle-time period (4 cycles).

The results are represented as mean ± standard error.

Adverse Events:

- No adverse events reported.

CONCLUSIONS

- **Pressure amplitude is a critical determinant** of sacral skin blood flow in individuals with spinal cord injury (SCI) during alternating pressure therapy.
- **Higher amplitude (75/5 mmHg)** alternating pressure promotes significantly greater blood flow compared to 65/15 mmHg.
- Cycle-time period (2.5-min. vs. 5-min.) does not significantly impact skin perfusion.
- Findings highlight the need **to optimize alternating pressure configurations** (for **APSS customization)** to enhance tissue viability and prevent pressure injury risk in people with SCI.
- **Limitations:** The small sample size (N = 10) limits generalizability. Skin blood flow was measured only at one anatomical site (the sacrum) and during short-term loading, which may not reflect long-term outcomes. Only two APSS settings were tested, and variations in SCI level or characteristics were not analyzed. The study lacked functional outcome measures and a control group.

KEY REFERENCES

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